MICROSCOPIC STUDIES ON THE CENTRAL NERVOUS SYSTEM OF REPTILES AND BATRACHIANS.

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ARTICLE III.

DIAMETERS OF THE NUCLEI OF THE LARGE NERVE CELLS IN THE SPINAL CORD (*continued*), ALSO OF THOSE WHICH GIVE ORIGIN TO THE MOTOR FIBRES OF THE CRANIAL NERVES.

SINCE writing article II of this series, I have met with nothing which could fairly be regarded as an objection to the law then presented, but have, on the contrary, noted many new facts which tend to strengthen it and widen its application. Nuclei which, by means of the prolongations of their surrounding cell masses, are related to muscles, have been carefully measured throughout the entire nervous system.

Scattered cells, like those found singly or in pairs near the course of the abducens nerve, with those which I have elsewhere described as existing in the meshes of the raphe of the alligator, and certain large cells in lizards, serpents, and turtles which appear to be connected with the acoustic or facial nerves, may all be classed as of doubtful function. Although the diameters of their nuclei may in some cases seem to furnish exceptions to the rule, so long as their anatomical relations remain obscure nothing can be definitely affirmed about them in this connection.

I would suggest, however, to those who may feel disposed to regard these cells as connected with the sense of hearing, that such a view involves giving to this apparatus, in its central portion, a structure almost identical with one universally admitted to be motor, like, for example, that concerned in raising the lower jaw; whereas in the central structures for vision and olfaction the cells are all very small.

Moreover, these large cells, found in the vicinity of the acoustic nerve in some lizards, turtles and serpents, are not found at all in the frog, while in the alligator their position indicates that they may be related to the motor branch of the fifth pair or possibly to the branch which supplies the depressor muscles of the lower jaw. The eminentia acoustica in the latter animal swarms with uniformly small cells and nuclei which are very probably the sole centres for the acoustic nerve, and in the same relative plane the same numerous groups of small cells can be seen in frogs and some lizards.

During the past summer, through the kindness of Prof. S. F. Baird, of the Smithsonian Institution, quite a number of valuable specimens have been placed at my disposal, among which may be mentioned Heloderma Suspectum, several serpents and one large example of Chelydra Serpentina.

Nuclei of the cells of the inferior (anterior) horns of the caudal, lumbar, dorsal, cervical and upper cervical regions of the spinal cord, in a large number of frogs of three species, two species of emys and two of land turtles, and in several alligators and lizards, including heloderma, have been measured. Of those found in the cervical and lumbar enlargements enough has been written already in the two preceding papers. The preponderance in average size is here in striking accord with that of the power of the

related extremities, and has since been repeatedly confirmed in frogs,* especially in longitudinal sections.

The caudal region in turtles and in those lizards which have few and delicate caudal muscles furnishes an interesting fact for consideration. In turtles the cell nuclei gradually diminish in size from before backward, and finally disappear altogether near the posterior portion, where the horns of gray matter present much the same appearance, as to structure, as that of the same parts in the dorsal region.

While in the alligator some of the largest cell nuclei are met with in this part of the cord, in those saurians, heloderma especially, which have comparatively little power in the tail, these elements are reduced gradually in size in the same sense as are those in the turtle. The same gradual transition is well marked in the caudal region of Scincus Erythrocephalus.

Stieda* gives measurements of nerve cells and their nuclei from the various parts of the spinal cord in Testudo Græca and Emys Europæa, agreeing with my own made later, and concludes as follows:

"I guard myself expressly against the supposition that the great differences in size between these three (large, medium-sized, and small) classes of cells are evidences of different physiological importance in these elements. I wish rather to assert that what is found in the spinal cord of the turtle can and must be used to support the contrary view. The fact that in the caudal and dorsal regions no large cells exist, but only medium-sized and small cells, while inferior (motor) roots are given out from these same regions,

* In the spinal cord of a bat which I have lately examined, the nuclei of the cervical region were found to be far more abundant than those of the lumbar region, and their average diameter somewhat greater. The muscles of the two pair of extremities bear the same sort of relation to each other.

"Ueber den bau des centralen nerven systems der amphibien und reptilien." Axolotl and Schildkröte, Leipzig, 1875, p. 40.

must have great weight against the conclusion that only the large nerve cells are connected with motor fibres." Accepting the passage as it stands I agree with him, but he has not fairly stated the ordinary view. It does not seem to me that "only the large nerve cells are connected with motor fibres," represents fairly the prevailing belief of anatomists and physiologists. That all the large nerve cells are thus connected is more accurately what is thought to be the fact. Of course, no one has ever claimed that the cells of origin of the oculomotorius, for example, were large cells or doubted that they were in connection with the fibres of the third pair of cranial nerves. Nerve cells, therefore, may be small and still be connected with motor nerve filaments. In the dorsal and caudal regions of the spinal cord of turtles the motor cells are small, because the muscles which they innervate are small. At the same time, it may be true that all large cells connect with motor filaments. To me, this is all in favor of ascribing difference in energy to different-sized cells or rather nuclei. The nucleus can be accurately measured, while the body of the cell can not be, and as the former probably constitutes the true cell, it has been preferred as an object of study in my researches.

MEASUREMENTS OF THE DIAMETERS OF THE NUCLEI OF NERVE CELLS WHICH ARE RELATED TO THE MOTOR FIBRES OF THE CRANIAL NERVES.

1. In four species of turtle, viz.: (1) Emys Floridana, (2) Emys Terrapin, (3) Testudo Polyphemus, and (4) Chelydra Serpentina, the following have been found to be the comparative dimensions of these nuclei :

The largest nuclei are found in the cells of the spinal cord and those of the nucleus basilaris of Stieda. Next to these in size are those of the centre for the motor root of the trigeminus, supplying with its fibres the elevator mus-

cles of the lower jaw and next those of the centres of the oculomotorius. This is true of all four species.

In the first three animals weighing about four pounds each, the nuclei for the respective centres were about equal, while differing in size in each individual as stated above. In the Chelydra Serpentina (snapping turtle weighing 24½ pounds) all the motor nuclei were much larger than those of the smaller specimens. The same rule holds true in frogs and alligators. The smaller the animal, the smaller the cell nuclei. I have not seen any mention of this fact in any works on anatomy.

2. The nervous centres of the alligator are especially well fitted for sections, and I have obtained three series of preparations, many hundred in all, showing the nuclei of the cells of origin of all the motor nerves. In this animal, the cell nuclei of the motor root of the trigeminus are found to occupy, as to size, the same middle rank between the nuclei of the oculomotorius and those of the motor roots of the spinal nerves, that they do in the turtle. These nuclei are remarkably large in both the alligator and snapping turtle.

3. In frogs the rule is even more strikingly illustrated than in the animals just mentioned. Anatomists have, as yet, made no centre for the hypoglossus, but it is interesting to note that, the nuclei of the cells forming the "nucleus centralis" of Steida, described and figured also by Reissner (the natural centre for this nerve), have a diameter just between that of the nuclei related to the oculomotorius and those related to the motor root of the trigeminus.

The constant variations in the size of these elements above indicated have been clearly illustrated by photography. By employing exactly the same degree of enlargement—by using the same objective and having the same distance always between the focusing screen and micro-

scope—for all the nuclei of the same animal, a very accurate representation of the actual condition is possible.

These photographs can now be examined at the library of the Academy of Medicine, the New York Hospital library, College of Physicians, Philadelphia, Surgeon-General's office and Smithsonian Institute, Washington, and at some university libraries. The same subjects, with over a hundred others, printed by the Artotype process on plate paper, showing the structure of the central nervous system of all the North American reptiles, will soon be published.

RECAPITULATION OF THE FACTS OBSERVED IN REGARD TO THE SIZE OF THE NUCLEI OF THE NERVE CELLS IN THE SPINAL CORD AND BRAIN OF REPTILES AND FROGS.

I. —FROG.

Diameters in divisions of Nachet's micrometer eye-piece with objective No. 5 :

Spinal cord, brachial enlargement	6.5 x 8.
" crural "	7. x 9.
Centre of motor root of trigeminus.	6. x 6.5
Possible centre of hypoglossus	4.5 x 6.
Centre of oculomotorius	3.5 x 4.5

II.—EMYS FLORIDANA.

Spinal cord, cervical enlargement	6. x 6.5
" lumbar "	6. x 7.
Dorsal region	2. – 4.
Caudal " gradually diminishing	6. – 2.
Centre of motor root of the trigeminus	5. x 5.
Cerebellum, large cells	4. x 5.
Centre of oculomotorius	3.5 x 4.5
Cerebrum	3.5 x 5.
Optic tubercles	3. x 3.5

III.—TESTUDO POLYPHEMUS.

Same as emys, except in spinal cord where the conditions are reversed in the two enlargements.

IV.—ALLIGATOR MISSISSIPIENSIS.

Spinal cord, cervical enlargement	6.5 x 7.5
" lumbar "	6.5 x 7.5
Centre of motor cord of the trigeminus	6. x 7.
" motor portion of the vagus	5.5 x 6.
" oculomotorius	5. x 5.
Large cells of the raphe	7. x 8.
Nuclei of eminentia acoustica	3.5 x 4.5
Sensitive cells of the vagus	3.5 x 4.5
Large cells of the cerebellum	3.5 x 4.5
Cerebrum and corpus striatum	3.5 x 4.5
Optic tubercles	2.5 x 3.

V.—HELODERMA SUSPECTUM.

With the exception of the caudal region of the spinal cord, where much the same scarcity and successive reduction of size of the nuclei exist as in the turtle, the diameters hold the same relation to each other as noted in the alligator. This remark also applies to the nuclei of Scincus Erythrocephalus.

VI.—ERYTHROCEPHALUS.

The nerve cell nuclei of small specimens are notably smaller than the corresponding nuclei of larger specimens of the same order. This rule only applies to orders, for some of the nuclei of Rana Pipiens, from the spinal cord, measure as much as those of the 24-pound turtle. The nuclei of the small lizards are, as a whole, proportionally larger than those of heloderma or the alligator.

The proposed law, formulated in my last paper, may now read as follows:

The nuclei of the so-called motor cells of the central nervous system have, in the same individual, average diameters, which are proportional to the power developed in the related muscles.

The writer, in conclusion, while admitting the incompleteness of his work, must at least claim to have demonstrated the fact that a hitherto unobserved relation exists between the size of a motor nucleus and that of its peripheral organ, the muscle.